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Mathematics Series

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NOTE

This standard has been converted from the original paper format to electronic format without substantive change in series coverage or grading criteria. The standard was reviewed to correct errors that may have been introduced during the conversion process. In some standards minor corrections were made such as updating references to other documents that may have become obsolete, or correcting minor typographical errors in the original standard. Any errors that remain due to conversion to electronic format should be minor and are not intended to change the meaning of the original standard.

If you find page references near the right hand margin of this standard they indicate the pagination of the official, printed version of this standard. For example, a notation "PAGE 2, 4/88, TS-87" would mean that (1) page two of the printed version begins here, (2) the date of issuance was 4/88, and (3) the Transmittal Sheet number was TS-87.

Mathematics Series

GS-1520

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SERIES DEFINITION

This series includes all positions the duties of which are to advise on, administer, supervise or perform work which requires professional education and training in the field of mathematics. This work includes research on basic mathematical principles, methods, procedures, techniques or relationships; the development of mathematical methods in the solution of a variety of scientific, engineering, economic and military problems, where the exactitude of the relationships, the rigor and economy of mathematical operations, and the logical necessity of the results are the controlling considerations.

This standard rescinds the standard for the Mathematics Series GS-1520, originally issued in June 1949 under the code of P-1540.

COVERAGE OF THE SERIES

Mathematics, which may be defined as the logical study of number and space, has been called the basic science since it forms the foundation for many of the natural, physical and social sciences. Mathematics may also be defined as the study of magnitude, quantities and numbers and their relationships, and the subsequent application of the knowledge derived therefrom to a variety of practical and theoretical problems.

Mathematics may be characterized by the elements, three in number, of its method or approach. It is precise, concise and rigorous -- precise in that the discipline of mathematics demands that all terms be accurately defined; concise in that redundancy is recognized and avoided and/or discarded; rigorous in that logical principles and adherence to these principles are inherent in the mathematical process. Since the elements that characterize mathematics may also characterize any number of disciplines which use mathematics as a tool or a language, it is somewhat difficult to distinguish positions which are truly mathematical in nature from those which are not.

Distinctions between mathematician positions and those involving other disciplines, even though coupled with substantial mathematical responsibilities, should be based upon the purpose of the work, the background of the incumbent, the methodology and approach involved, career patterns, and the *requirement* for application of a professional knowledge of the principles of mathematics.

In the final analysis, the best single indicator as to whether a position should be classified in the Mathematics Series or to an appropriate subject-matter series may be the purpose of the work performed as determined by responsible management.

EXCLUSIONS

Excluded from this series are the following classes of positions:

1. Positions engaged in routine standardized phases of mathematical work which do not require professional knowledge of mathematical principles and methods are classified in the Mathematics Technician Series, GS-1521.
 2. Positions engaged in the administration, supervision or planning of programs for a digital computer systems activity or the operation of digital computers and peripheral equipment which do not require professional mathematical knowledges and skills. (See Digital Computer Occupations, GS-330 through GS-334. See also the section of this standard entitled *Classification of "Programmer" Positions*.)
 3. Positions engaged in the administration, supervision, or performance of professional work or the providing of professional consultation in the application of statistical theories, techniques and methods to the gathering and/or interpretation of quantified information are classified in the Statistician Series, GS-1530.
 4. Positions engaged primarily in the development and application of mathematical, statistical and financial principles to problems or programs involving life and property risks and contingencies are classified in the Actuary Series, GS-1510.
 5. Positions engaged primarily in the design, development and adaptation of mathematical methods and techniques to statistical processes, or the performance of research in the basic theories and science of statistics are classified in the Mathematical Statistician Series, GS-1529.
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6. Positions engaged in professional and scientific work in the biological and/or physical sciences or engineering or architecture in which the primary requirements are the knowledges and techniques of a recognized subject-matter specialty even though such positions may include substantial amounts of professional mathematics work are classified in the appropriate series of the Biological Sciences Group, GS-400, the Physical Sciences Group, GS-1300, or the Engineering and Architecture Group, GS-800.
 7. Positions engaged in the administration, direction, supervision, and performance of professional and scientific work in which the primary requirements are knowledge and skill in the application of operations research methods and techniques to operational problems even though such positions may include substantial amounts of professional mathematics work (i.e., positions which may be adequately filled through the selection of experienced researchers from disciplines such as the natural, physical, or social sciences

or engineering as well as mathematics are classified in the Operations Research Series, GS-015.

THE WORK OF MATHEMATICIANS IN THE FEDERAL SERVICE

Traditionally, with respect to the work performed, mathematics has been divided into two generic groups -- pure or abstract mathematics and applied mathematics. Pure mathematics, sometimes referred to as research in mathematics, may be defined as the study and development of principles for their own sake and possible future usefulness rather than immediate usefulness. Applied mathematics concerns itself with the mathematical aspects of the physical, natural and social sciences. For example, a mathematical structure, utilizing, in addition to the purely mathematical concepts of space and number, the notions of time and matter belongs to the realm of applied mathematics. In a restricted sense, the term refers to the use of mathematical principles as tools in the field of physics, chemistry, engineering, biology and the social sciences. Relatively few mathematicians are conducting research in pure or abstract mathematics; there are, however, relatively large groups of mathematicians working in applied mathematics, and it is, for the most part, the latter group with which this standard is concerned.

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Traditionally, the role of the mathematician has been the provision of advisory and support services in his specialty to his employing organization, and performance in this role has tended to place him outside the mainstream of his organization's creative activities. This traditional role has not been eliminated today, primarily because higher mathematical skills are now prevalent in many professional groups in the Federal service and professional mathematical assistance can be utilized more effectively now than ever before. In recent years, probably within the last fifteen to twenty, two highly significant trends have emerged which have served both to increase the number of mathematicians employed and to place them squarely in the mainstream of their organization's creative activities.

The most easily recognized trend, and the more spectacular of the two, has been the rapid advancements in the development and utilization of high speed electronic computers. The implementation of automatic data processing techniques within the Federal service was accompanied by the acquisition of a wide variety of electronic digital and analog computers at both field and headquarters activities. In many cases, the mathematician actively participated in the design and development of these computers which were tailored to a variety of research and development, inventory management and accounting applications. Increasing computer usage has brought with it unprecedented demands for professional mathematicians, particularly those skilled in numerical analysis and methods of computation, and helped to bring about and accelerate the second significant trend, the team or project concept.

Less obvious and, therefore, less spectacular than the impact of the electronic computer, the growth of the multi-disciplinary team is fundamentally the more significant of the two trends. Through his direct participation in the team effort, the professional mathematician has emerged as an active participant in and vigorous contributor to the creative process. The team obviously cannot function effectively without complete and clear communication between the individuals who comprise the membership of the team. Mathematics, typically, provides the precise and clear language necessary for unimpeded communication with each other and the solution of the problems confronting them. The mathematician characteristically plays a key role in the early phases of the development of complex systems, often referred to as "systems research." In systems research, the pressing requirements of time, money, and complexity frequently demand exact definition of terms, rigorous formulation of questions and logical answers to them before the nature of the problem can be fully understood and the requirements for solution adequately formulated. The mathematician, who typically possesses more intensive training in the manipulation of abstract ideas and is better versed in the use of mathematics as a language than other professionals, can provide a positive service to the team in this process of systems research. When the problem is thoroughly understood, the requirements established, and the reduction of these requirements to "hard and soft ware" has begun, the services of the mathematician are likely to continue in many important areas but at a decreasing rate. It is in this early phase, when general principles, frequently unfamiliar ones, must be examined critically and without semantic or logical ambiguity that the professional mathematician is in greatest demand. In performing this role, he has transcended the support function of the consultant and become a working member of the team, fulfilling a central responsibility in the accomplishment of the mission of his organization.

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THE SIGNIFICANCE OF THE MATHEMATICAL TECHNIQUE OR METHOD

The dynamic nature of the field of mathematics has stimulated and will, no doubt, continue to stimulate the discovery, development and implementation of new and useful mathematical techniques and methods. Additionally, useful portions of what may be loosely termed "earlier developments in mathematics" are continually being rediscovered, refined and applied to contemporary problems. To illustrate, the body of mathematical theory formulated by George Boole, while serving to stimulate the efforts of Russell, Whitehead, and others in the development of symbolic logic, remained in relative obscurity for the better part of a century because it appeared to have little potential for practical application. With the advent of the high speed electronic computer, however, Boolean Algebra has become a highly useful mathematical technique and is now in general use throughout the mathematical community.

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In the past, the classification of mathematician positions depended, in part, on the level of difficulty of the mathematical methods used, examples of which were included in the classes.

The fact that different mathematical methods and techniques are of different degrees of difficulty is irrefutable. While level of difficulty must be considered, it is unrealistic to state categorically that a given method or technique is typical of and restricted to a given class; absolutes in terms of the mathematical method or technique used at the various levels simply do not exist. As an example, mathematicians whose assignments involve the solution of boundary value problems typically use Bessel's functions in their work. Both the senior mathematician and the trainee may use this method, and it would not, therefore, follow that its use is characteristic at either the GS-5 or the GS-13 level.

The value of material concerning the relative degree of difficulty inherent in the various mathematical methods and techniques becomes meaningful to the classification process only when viewed in proper perspective, e.g., as an *indicator* of the difficulty of the work performed rather than as an absolute measurement of same. Careful consideration must be given to the degree of sophistication of the application, the extent of supervision received, precedents and guidance available, the scope of the assignment, and the usefulness of the end product as well as the method or technique utilized per se. The senior mathematician and the trainee both may use matrix theory and methods in accomplishing their assignments, but this superficial similarity disappears when the differences in skills, supervision received, nature of the problem and significance of assignments are examined.

CLASSIFICATION OF "PROGRAMMER" POSITIONS

As noted above, the expanding utilization of high speed electronic computers within the Federal service has resulted in significant increases in the number of mathematicians employed. This increase has been particularly evident at Federal laboratories where mathematicians, organized into teams or groups, use mathematical and numerical expressions to solve scientific and technical problems with the aid of computers. The mathematician utilizes the computer as an adjunct to his own skills in the resolution of problems in such fields as the physical, natural and social sciences and engineering. To assure compatibility between his skills and knowledges and the capacity and capabilities of the computer and to achieve the desired results, the mathematician characteristically develops or modifies an already existing mathematical model. Federal laboratories also utilize large numbers of mathematicians in scientific computation and data reduction work which involves, in large measure, the translation of mathematical equations into compatible computer programs. Techniques which lend themselves well to computer applications include matrix methods, ordinary and partial differential equations, Monte Carlo methods and the previously noted Boolean Algebra. Since many mathematicians perform duties directly related to computer applications, it is apparent that advances in computer technology and their resultant effects on the field of mathematics must be recognized and included in the classification and evaluation of mathematician positions.

In appraising the nature and importance of the programming function to the mathematician, the classifier should consider the following:

1. The size, capability and complexity of the computer have little significance from a level standpoint except as they affect the complexity of the job to be accomplished. Many of the newer models, in some cases, occupy entire rooms, are incredibly complex in structure, and have the capacity to accomplish truly prodigious mathematical feats, yet are actually easier to program than many of their less imposing predecessors. Advances in machine language systems have also increased the scope of computer applications and, at the same time, made it easier to program the computer to accomplish more difficult tasks.
 2. The computer, as used by the mathematician, is basically a device to complement and supplement his basic mathematical skills and knowledges. The important fact to consider in evaluating positions which require the utilization of computers in the accomplishment of assigned tasks is "Does the position require full professional skills and knowledge in mathematics?" If the paramount requirement for a particular position is skill and ability in computer programming and the requirement for the application of basic mathematical skills is minimal, nonexistent, or technical in nature then that position, regardless of organizational, location, should not be classified in the GS-1520 Series.
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3. Some mathematicians occupy positions in which the level of the computer programming work performed exceeds that of the, professional mathematics work performed. In these situation both the Mathematics Series, GS-1520, and the Digital Computer Programming Series, GS-331 should be used to determine the level of work performed even though the position is classified in the Mathematics Series on the basis of professional knowledges required for full performance of assigned duties. The preparation and maintenance for the record of a brief summary of the basis for the title and series determinations in such cases would serve as a convenient reference for any subsequent job reviews and/or future recruitment and staffing purposes.
 4. In evaluating and classifying positions requiring both mathematical and computer programming knowledges, skills and abilities, it is important that the classifier consider such factors as lines of promotion, career development "ladders," management requirements and the purpose of the work performed along with the classification material contained in this standard and the GS-331 Series to assure accurate series and level determinations.

SPECIALIZATIONS AND TITLES

Many positions in this series tend to specialize in terms of subject-matter application, mathematical specialties, combination with other disciplines and functional areas of effort. In

some of these areas, both research and operating types of positions exist. Because of the diversity and relatively large numbers of positions included, in this series, a variety of specializations could be established which would appear valid from a purely descriptive standpoint. The establishment of such specializations would, however, unduly fragmentize the occupation and offer only small amounts of real benefit in the recruitment process. Selection of candidates for specific positions requiring highly specialized knowledges and skills can be accomplished best by considering both the specific requirements of the position and the qualifications of the candidates referred through established recruitment sources, competitive or noncompetitive, as appropriate. Since classification of mathematician positions by subject-matter application, mathematical specialty, combination with other disciplines or functional responsibility is neither necessary nor practical for personnel management purposes, no specializations are established for this series.

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The basic title for all positions in this series is "Mathematician." Supervisory positions will be identified by adding the prefix "Supervisory" to the basic title.

CLASSIFICATION CRITERIA

This standard provides grade-level guides for nonsupervisory, nonresearch positions and does not apply to positions involved in the conduct of basic and applied research in the field of professional mathematics. The following factors are used to determine the degree of difficulty and complexity and the level of responsibility of such mathematician positions: Assignment Characteristics ; Level of Responsibility; and Professional Qualifications required.

1. Assignment characteristics

This element takes into consideration the kind and level of work performed, the scope and intensity of the work performed and the relative importance attached to the results achieved by the mathematician.

Assignments performed by mathematicians are characterized by great variation in kind and difficulty. They range from the application of standardized methods to isolated tasks to the planning and execution of assignments of major importance which involve the use of highly sophisticated mathematical methods and techniques or the performing of consultative or advisory services on the mathematical aspects of a large-scale engineering, scientific or economic program. The level of difficulty may be affected by the availability and reliability of existing guidelines (precedents, reference works), the need to develop new methods or modify and/or adapt existing methods of operation (originality), and the complexity and sophistication of methods and techniques used. The degree of importance attached to the results of a given assignment span a range from very limited (e.g., the performance of a few

limited tasks under close technical review which constitute partial solutions of routine noncomplex problems) to very substantial (e.g., full responsibility for the accomplishment of an assignment of major scientific or technical importance).

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2. Level of responsibility

This element considers the mathematician's responsibility for making recommendations, conclusions and decisions, the active participation of the supervisor in the work ,process, review of results and conclusions and the nature and effect of supervisory, technical and administrative controls on the work performed. The requirements for the making of recommendations and conclusions range from routine and immediate considerations of the assignment to highly significant and far-reaching scientific commitments of great consequence. This element may be qualified by the supervisor through controls on (a) the authority delegated to the mathematician, (b) the degree of freedom from instruction and review enjoyed by the mathematician, and (c) the extent to which the work of the mathematician is accepted as authoritative.

3. Professional qualifications required

This element considers the extent of professional experience and training in mathematics and other knowledges and skills required to assure full performance of the employee's assignments and includes both academic training and professional work experience. These requirements range from the basic knowledges of mathematical methods, techniques, and principles found at the entrance level of the comprehensive knowledges and finely honed skills apparent at the higher levels. This element also includes the extent of knowledges required at the various levels in such areas as standard and special reference texts, technical publications, state of the art, instrumentation, equipment and mathematical aids and devices.

NOTES ON THE USE OF THE STANDARD

1. The criteria noted above are used together as guides to grade-level determinations. To warrant classification to a specific grade level, a position must substantially adhere to the three criteria established for that grade level.
2. The illustrative material included under Assignment Characteristics reflects current assignments, functions and methodology in the field of mathematics. Since mathematics is a dynamic occupational area, this reliance on contemporary illustrative material presupposes, to a greater or lesser extent, some obsolescence in the material itself. This illustrative material may become less reliable as the occupation evolves. In addition, the

user is cautioned against excessive reliance on a given function or assignment as an indicator of work performed only at a specific level, e.g., work involving orbital dynamics of earth satellites as shown in example 3 at the GS-12 level may be performed at levels above and below GS-12.

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3. This standard is not intended for use in the evaluation of positions engaged in the performance of basic and applied research. The Research Grade-Evaluation Guide should be used to evaluate research positions at all levels.

Many mathematicians perform no research at all and others perform only limited elements of research in conjunction with assignments designed to achieve other ends, but many positions are not as well delineated. The mathematician who serves in a consultative capacity to a research team studying the circuitry for a high speed electronic computer and does not participate fully in the substantive aspects of the work does not perform research as contemplated above. Accordingly, his duties and responsibilities do not fall within the evaluative capacity of the Research Grade-Evaluation Guide. On the other hand, some mathematicians engaged in consultative work perform assignments involving "systematic, critical and intensive investigations, experiments and explorations," "the pursuit of new theories, principles, and methods," and "the extension of established theories, principles and methods" which fall within the purview of the Research Grade-Evaluation Guide. The fact that a mathematician may perform his assignments in a research facility does not, by itself, mean that the position is to be classified by use of the Research Grade-Evaluation Guide. The best single indicator as to whether or not a position requires the execution of research as a primary function or duty is the purpose of the work performed as determined by responsible management.

4. As noted in the grade-level discussions, the direction of the efforts of other professional and technical employees occurs even in positions which are essentially nonsupervisory. Positions in which supervisory responsibilities are an important factor are evaluated by reference to Part II of the Supervisory Grade-Evaluation Guide.

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5. Positions involving combinations of full knowledges in two or more disciplines or which could be adequately filled through the selection of individuals from more than one discipline may be classified by use of the interdisciplinary classification technique found in Section II, Part J, of the Introductory Material to Position Classification Standards.
6. This standard does not provide specific guidance for the application of the "impact of man on the job" concept nor does it preclude such application. There are some nonresearch positions in which the professional qualifications of the incumbent will materially affect the grade level of the position. Even though this standard provides

reasonable recognition of the professional skills and knowledges required and expected at each grade level, it is recognized that some work situations require unusual professional competence as is sometimes the case in high level consultative or advisory work. Accordingly, when the circumstances of the work situation permit, this factor should be taken into consideration in the evaluation.

7. This standard does not include criteria for the atypical non-supervisory positions above the GS-13 level. Generally, position above the GS-13 level involve the personal performance of research or substantial supervisory, administrative or program responsibilities. The absence of criteria for nonsupervisory positions at grades GS-14 and GS-15 does not preclude the evaluation of these positions by extension of the classification factors discussed in this standard and the application of general classification principles.

MATHEMATICIAN GS-5

Assignment characteristics

This level is the entrance or beginning level in the field of mathematics within the Federal service and requires a professional knowledge of the basic principles, theories, and methods of mathematics. Assignments are selected to provide experience and training in the application of basic professional skills, knowledges and abilities, the use of mathematical methods, procedures and techniques and a knowledge of pertinent source materials. GS-5 mathematicians also receive assignments designed to acquaint them with agency programs, policies, procedures and regulations to advance their knowledge of the subject-matter area with which the organization is concerned, and to provide a basis for more responsible assignments.

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Level of responsibility

Mathematicians GS-5 receive close and continuing supervision and detailed instructions on the use of selected specific methods, procedures and techniques. Work in progress and results are closely checked for accuracy and to evaluate the rate of development of the employee. As the employee progresses professionally and becomes more competent in certain work areas, supervisory control over work in progress in these areas is gradually relaxed, but results are carefully reviewed and evaluated for accuracy. Frequently, beginning mathematicians may be assigned duties of a routine nature not requiring a full knowledge of mathematical principles and resembling the types of duties usually assigned to technicians. Such assignments are performed in conjunction with other tasks requiring professional skills for training and developmental purposes to prepare the employee for higher level professional assignments.

Professional qualifications required

Mathematicians GS-5 must have a good working knowledge of the principles, theories, and methods of mathematics, a knowledge of and ability to use standard reference works, slide rules, mechanical calculating devices, mathematical tables, and, as required, special purpose mathematical devices and aids. Mathematicians at this level must also possess an aptitude for learning new and advanced methods and techniques and demonstrated ability to progress to higher levels within the field of mathematics.

MATHEMATICIAN GS-7*Assignment characteristics*

Mathematicians GS-7 perform a variety of mathematical analyses, computations and measurements of limited scope, requiring skill and care in implementing standard procedures and methods. Mathematicians GS-7 exercise very little independence of operation in all phases of an assigned project. Typically, they perform assigned tasks as an assistant to a mathematician or subject-matter specialist of higher grade who defines or explains the objectives, limits, methods of operation, critical points and anticipated results of the assignments made and reviews the results produced. Assignments are selected to provide a basis for the development of the employee's potential for higher level work in the field of mathematics. Mathematicians GS-7 perform a wider variety of analyses, computations and measurements than Mathematicians GS-5 and learn to use more advanced methods, techniques, devices and instruments. They make limited judgments in selection of alternative methods of operation and in modification and adaptation of standard methods and techniques. They exercise some originality in the preparation of reports, memorandums or descriptive materials summarizing the accomplishments and results of the tasks assigned. Assignments may also include duties usually performed by a technician. As at the GS-5 level, these duties are performed for developmental purposes to prepare the employee for higher level professional assignments.

Level of responsibility

Mathematicians GS-7 have relatively little opportunity to render decisions or exercise much judgment in their work, since their assignments are normally developmental in nature and designed to prepare the employee for more responsible professional work in the field of mathematics. Mathematicians at this level are given assignments requiring the use of standard or established methods and procedures with which they have become familiar or are given specific instructions in the use of new or unfamiliar methods and procedures when necessary. Some judgment is exercised in the application of basic mathematical principles and procedures to the tasks assigned, the selection of alternative methods of operation and the modification of standard methods or procedures. Completed assignments are reviewed fairly

closely by a mathematician or subject-matter specialist of higher grade for the consistency, adequacy and thoroughness of application of the selected method, technique or procedure and the accuracy, clarity and reasonableness of the results produced. Unusual conditions or unanticipated obstacles are referred to the supervisor for assistance and advice as they occur.

Professional qualities required

In addition to the experience and training required at the level mathematicians should possess some familiarity with an appropriate specialized subject-matter area, and, as required, the aptitude and ability to learn and use the programming and operating systems for the general or specialized purpose high speed electronic computing machines and related on- and off-line peripheral equipment common to the organization. They must possess the ability to select and apply standard mathematical methods and techniques to problems assigned and prepare accurate and factual technical correspondence. They must also possess the aptitude for learning new and advanced techniques and methods and demonstrated ability to progress to higher levels within the field of mathematics.

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MATHEMATICIAN GS-9

This level differs from the GS-7 level in two important respects: (1) The employee works more independently than at the GS-7 level, receives less supervision and exercises a higher degree of judgment in the accomplishment of his assignments, particularly in the selection of methods and the formulation of tentative conclusions, and (2) the employee assumes responsibility for the accomplishment of assignments which are combinations of various individual tasks similar to those performed at the GS-7 level, but which, when taken cumulatively, are more difficult, more complex and broader in scope than the isolated individual tasks performed at the GS-7 level.

Assignment characteristics

Mathematicians GS-9 perform a variety of mathematical analyses, computations, measurements and evaluations on assigned individual problems or portions of larger problems or projects. Their assignments are of moderate difficulty and complexity and typically require the use and, as appropriate, the modification and adaptation of standard mathematical methods and procedures in their accomplishment. At this level, guidelines which ordinarily take the form of similar completed problems are usually available. Originality required of the Mathematician GS-9 is typically restricted to the selection, modification and adaptation of standard mathematical methods and techniques. Assignments may involve a variety of subject-matter applications and mathematical methods or may be restricted to one narrow specialization (e.g., rigid body trajectory computation), or one technique or method (e.g., differential equations) in either situation, the assignment is relatively limited in depth and

scope. Some Mathematicians GS-9 assume responsibility for the technical guidance and instruction of lower graded professional employees on a noncontinuous basis, usually for the duration of a given assignment.

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Typical of the kinds of assignments and technical work performed in the class are the following:

1. Participates in logistical studies involving the evaluation and application of standard mathematical methods in the solution of various problems, e.g. the application of theoretical methods of finite differences in the form of exponential smoothing to the problem of forecasting future demands for material and the development of mathematical rules to interpret usage and demand data and mortality rates.
2. Performs mathematical analyses and evaluations on assigned problems or phases of problems. Works under the direct supervision of one or two research scientists concerned with the development and evaluation of mathematical approaches to theoretical aerospace problems. Assignments may involve, in addition to the application of mathematical methods and techniques, the application of some knowledge of the physical relations involved in some phase of aerospace research.
3. For assigned projects, sets up differential equations on an electronic computer to obtain calculated transient engine curves; formulates and analyzes equations, plans and initiates computer configuration and Interprets the results.

Level of responsibility

Mathematicians GS-9 have greater opportunity to exercise judgment, formulate conclusions and make suggestions and qualified decisions than at the preceding level, since supervision received is usually general. Typically, the supervisor explains the objectives of an assignment, suggests various approaches and discusses available precedents, degree of accuracy required, critical points, test criteria and anticipated results. The employee is expected to accomplish, the detail planning and execution of his assignment, referring only the more difficult or unusual problems encountered to the supervisor, usually with recommendations for resolution. This relative independence of operation requires the Mathematician GS-9 to evaluate alternative methods of approach, select and apply the most appropriate method and correctly analyze and interpret his findings. Typically, the employee prepares a report, graph, table, or other descriptive document, which is subjected to close professional review by the supervisor or assists in the preparation of such a document which is closely reviewed by higher level authority.

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Professional qualifications required

Mathematicians GS-9 must have a good knowledge of the principles, theories and methods of mathematics, and the capacity to adapt much of this knowledge to the specialized requirements of their assignments. They are expected to acquire and make use of practical knowledge of appropriate specialized subject-matter areas, and, as required, have a good knowledge of the programming methods, operating procedures, data processing principles and electronic computer facilities common to the organization. They must be able to exercise judgment in the selection and modification of appropriate methods of operation, the analysis and interpretation of results, and the preparation of reports.

The skills and knowledges required at this level differ from those required at the preceding level primarily in the degree of sophistication with which they must be applied to the practical problems encountered by the mathematician in the accomplishment of his assignments.

MATHEMATICS GS-11

This level differs from the GS-9 level in: (1) complexity, difficulty, and scope of the assignment, (2) increased freedom from supervisory instruction, (3) greater responsibility for planning the accomplishment of an assignment, or (4) greater responsibilities for interpreting, evaluating, and reporting findings and conclusions.

Assignment characteristics

Mathematicians GS-11 are independently responsible for the accomplishment of assigned individual problems or portions of larger problems or projects which require sound judgment and a good knowledge of the field of mathematics. Assignments are difficult and complex, require considerable planning to assure adequacy of results, and demand careful evaluation and interpretation of findings and conclusions. At this level, guidelines directly pertinent to the assignment frequently require modification and may be unreliable or conflicting. Some originality is required of the Mathematician GS-11 in the development of his plan of attack or approach to the assignment.

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Typical of the kinds of assignments and technical work performed in the class are the following:

1. Develops and controls programs involving the solution of sets of simultaneous nonlinear differential and algebraic system equations by use of electronic computing equipment; transforms and analogs equations for machine solution; solves certain sub-sets of equations or calculates complete run for one set of parameters; analyzes and coordinates

processes; operates computer console and carries out schedule of runs; observes equipment and parameters of solutions and takes corrective action when trouble is discovered; and interprets directions about parameter changes related to system or machine equations, making computer changes to produce desired results in the system.

2. Applying a knowledge of basic relationships peculiar to the area of application and following precedent in the form of related studies, formulates problems, selects range of values and intervals, and determines method of solution best fitted for types of calculations required. Accomplishes calculations required, spot-checking results for expected trends and for consistency. Organizes results for presentation in publication form and prepares rough draft discussion of methods used in obtaining results. Determines methods of solution for new types of work and makes changes to adapt established procedures to new problem conditions. May exercise technical supervision over a group of lower grade mathematicians engaged in the establishment of detailed computing procedures and the performance of theoretical computations requiring a knowledge of higher mathematics.
3. Establishes theoretical performance characteristics of rocket and/or jet propelled vehicles by formulation and solution of the pertinent partial and ordinary differential equations to predict critical dimensions or parameters; uses principles of aerodynamics and advanced mathematical techniques to theoretically extend performance characteristics.

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Level of responsibility

Mathematicians GS-11 are fully responsible for planning, organizing, scheduling and executing their assignments. They receive very general instructions regarding their assignments, consult their supervisors only as necessary, typically when unusual difficulties are encountered, and are expected to independently carry their assignments to a successful conclusion. Mathematicians GS-11 receive general supervision from a mathematician or subject-matter specialist of higher grade who outlines objectives, proposes, methods of approach and reviews the final results for general performance, conformity and adequacy.

At this level, recommendations and conclusions are an inherent part of the work process and are expected to be the logical, accurate and comprehensive products of a trained and experienced professional mathematician. Review is concentrated on adequacy of the recommendations and conclusions presented and their applicability to the requirements of the assignment. This level differs from the preceding level primarily in the greater significance and scope of conclusions and recommendations commensurate with assignments.

Professional qualifications required

In addition to the skills and abilities required at the preceding levels, the employee should possess a good knowledge of a specialized branch of mathematics directly applicable to the,

assigned area of responsibility, i.e., numerical analysis, special functions, matrix theory, computation methods, etc. As required, the employee should possess a detailed knowledge of the languages, systems, procedures and computer facilities common to the organization. The employee must possess the ability to independently accomplish his assignments with a minimum of supervision. The skills and knowledges required at this level differ from those required at the preceding level primarily in the extent of their application to (1) a broader spectrum of assignments, or (2) a narrow area of specialization in greater depth and intensity.

MATHEMATICIAN GS-12

This level differs from the GS-11 level in: (1) responsibility for the formulation and development of new mathematical methods and techniques, (2) application of the skills and knowledges of a specialist with extensive experience and/or training in a specific subject-matter area or branch of mathematics, or (3) assumption of project or team leader responsibility.

Assignment characteristics

Mathematicians at GS-12 are independently responsible for the planning and accomplishment of assignments of considerable difficulty and complexity which typically require the formulation and development of new techniques and methods in a specialized branch of mathematics or for a specific subject-matter application. Assignments are typically of considerable breadth and scope or of considerable depth and intensity in a narrow area of subject-matter or mathematical specialization. At this level, guidelines and precedents applicable to the more demanding assignments may be inadequate, inappropriate, or, frequently, lacking. Considerable originality is typically required of the Mathematician GS-12 in the formulation and development of new techniques and methods for specific and specialized applications. Many mathematicians at this level specialize in a subject-matter area (e.g., orbital dynamics), or in a specific branch of mathematics (e.g., numerical analysis) and may perform consultative and/or advisory services in their specialties to other mathematicians and subject-matter specialists. Frequently, mathematicians at this level serve as team or project leaders and are responsible for providing technical guidance to and coordinating the efforts of the professional and nonprofessional employees assigned to them for the duration of the project or assignment.

Typical of the kinds of assignments and technical work performed are the following:

1. Plans and organizes the mathematical phases of research and development projects within an assigned area or areas which involve a variety of complex interrelations and problems. Develops systematic and efficient procedures for carrying out many types of computation within the subject-matter area or areas. Executes or coordinates the

application of mathematical and computational methods to complex analytical and theoretical problems. Works closely with research scientists in the development of methods and procedures for the analytical phases of new research techniques. Works closely with research scientists in carrying out individual assignments and in providing mathematical and computational services for a research segment. May direct the work of a group of mathematicians and mathematical technicians in providing mathematical and computational services for theoretical and experimental investigations.

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2. Serves as a project mathematician in a computation and analysis laboratory. Conducts the technical work of one or more of the various projects which are designed to enhance the overall programs of the laboratory in support of a novel area of research. Technical capabilities associated with this level of responsibility are important to the achievements of the organization as a whole, since the project efforts represent the application of advanced theories and concepts reflecting the state of the art. Accomplishes assigned projects in their entirety, directing overall effort towards fulfilling all objectives of the individual projects. Plans related portions of the projects, establishes the work interfaces and levels for these portions; may supervise subordinate personnel assigned to him for carrying out the projects. May be required to direct several projects related to a single program or to direct several projects representing two or more separate programs. Confers with senior members of the technical staff on problems involving the interpretation of the programs of the laboratory and serves as liaison to other agencies having an interest in the activities of the laboratory.
3. Investigates orbital dynamics of earth satellites to ascertain methods by which these dynamics may be derived and predicted from analyses of tracking data obtained by surveillance activities; assists in the determination of objectives of such analyses and priorities of major phases; shares in the responsibility for providing consultative services to scientists in other Federal agencies on projects associated with re-entry studies; formulates mathematical models and associated computation methods for use in the analysis of special problem areas and evaluation of system performance; develops data to facilitate choice of optimum time of satellite launch; reduces orbital equations by use of simplifying assumptions which cause no adverse effects on final results.

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Level of responsibility

Mathematicians GS-12 typically receive assignments in broad general terms from the supervisor who outlines the assignment and, in concert with the employee, determines the

objectives, significant areas, priorities and limitations. Technical guidance received is minimal and typically consists of an initial discussion of the assignment and potential methods of attack and subsequent informal conferences to keep the supervisor informed of the rate of progress, difficulties encountered, unusual developments and unanticipated obstacles. Problems of a particularly difficult or unusual nature or those with implications beyond the immediate scope of the assignment are brought to the supervisor for assistance. Recommendations and conclusions are typically accepted as technically sound. Review of the results and findings is concentrated on general conformity and adequacy and the degree to which objectives have been met; technical accuracy, completeness, judgment and applicability of methods are not reviewed in depth. Mathematicians GS-12 usually are authorized to make recommendations or commitments on the basis of the results and findings derived from their assignments and related work experience to representatives of other organizations within the agency and occasionally outside the agency.

The recommendations and conclusions at this level differ from those at the GS-11 level primarily in: (1) their significance; the Mathematician GS-12 typically has commitment authority within the scope of his assignments, and (2) their dependability; the work of the Mathematician GS-12 is that of a mature professional and maybe relied upon to be accurate, complete and scientifically sound.

Professional qualifications required

In addition to the skills and abilities required at the preceding levels, the employee should possess a thorough knowledge of a specialized branch of mathematics directly applicable to the assigned area of responsibility and the ability to apply it to assignments which are difficult, complex, and significant. The employee must possess the ability to formulate and develop new mathematical methods and techniques and, toward this end, should have a high degree of familiarity with recent mathematical advances in his particular field of endeavor. The skills and knowledges required at this level differ from those required at the preceding level primarily in the degree of their intensity, i.e., those of a mature professional employee who has demonstrated his ability to effectively cope with the advanced aspects of his profession.

MATHEMATICIAN GS-13

This level differs from the GS-12 level in: (1) the presence of full commitment authority within the limits of established policy; (2) recommendations, conclusions, findings and results are accepted as authoritative and frequently form the basis for major policy determinations and binding commitments for the organization involved (3) the complexity and novelty of assignments.

Assignment characteristics

Mathematicians GS-13 are independently responsible for the planning, development, evaluation and execution of assignments which are of broad scope, and marked complexity, significance, and importance. The Mathematician GS-13 typically provides advisory services to other mathematicians and subject-matter specialists in a branch of mathematics or in the application of mathematics to a specialized subject-matter area. At this level mathematicians are often sought out for advice and assistance by other mathematicians and subject-matter specialists who are competent professionals in their own right. Assignments typically call for the formulation and development of new mathematical methods and techniques, the reduction of complex technical findings to "rules of thumb" and the promulgation of guidance material, e.g., tables, constants, routines and technical generalizations, for use by other professionals. These assignments are frequently performed in areas where precedents are scanty, inappropriate or nonexistent and require careful planning, efficient coordination of effort, the application of mature practical and scientific judgment, and a high degree of originality. As at the GS-12 level, Mathematicians GS-13 frequently serve as team or project leaders.

Typical of the kinds of assignments and technical work performed in the class are the following:

1. Investigates, using numerical analysis and other mathematical techniques, complex physical problems working, in collaboration with subject-matter specialists; or develops computation programs for use in the mathematical analysis of such problems. Applies ingenuity in developing the most efficient and effective analysis possible for computational problems which are complicated by numerous variables and several parameters. Provides technical guidance to lower grade mathematicians and programmers whose work supports his study. Reviews and evaluates the results of computation programs run in relation to his studies. Develops and applies new mathematical expressions for use in solving or computing research problems.
2. Serves as an adviser and authority to members of the laboratory and other laboratories of the activity on computer program methods and applied mathematics. Furnishes advice regarding solution on modern electronic computers of those problems requiring advanced mathematical and logical procedures; devises and implements pilot programs in order to

ascertain the feasibility of machine solution of proposed problems on which - advice has been sought. Conducts studies in numerical analysis and computation techniques and engages in the design and application to computers of language structures containing mathematical and subject-matter characteristics suitable for computer utilization for information retrieval projects.

3. As project leader accomplishes long-term projects requiring dynamic analysis of automatic weapons systems; conducts studies involving the formulation and solution of complex problems in the field of mathematics to determine behavior of the system and components or to develop optimum parameters and boundaries; makes mathematical analyses to determine dynamic properties of particles, rigid and nonrigid bodies, structures, and electronic circuitry; writes equations of motion for dynamic analysis of missile systems after determination of configuration. As weapons systems expert, formulates and solves problems utilizing applied mathematics in the analyses of complex systems through derivation of mathematical models suitable for solution on an electronic computer; serves as an expert on simulation methods, computer techniques, and the utilization of operational mathematics in weapons systems analysis; acts as mathematical consultant to the laboratory on problems involving theory of dynamic stability and analysis of servo-mechanisms.

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Level of responsibility

Mathematicians GS-13 typically play a key role in the problem definition aspects of their assignments based on their work experience, assignments, and interests and those of their associates. Assignments received from the supervisor are typically broad, very general outlines of the assignment, priorities, policy limitations and urgency. Subsequent technical supervision is confined to policy determinations, coordination of the assignment with the work of others, and advice on the continuation, termination, reduction, or amplification of the assignment. Recommendations and conclusions are accepted as authoritative. Review of results and findings is concentrated on effectiveness in meeting objectives and for general conformity to established policy; validity, accuracy and judgment in such matters as the selection of methods and techniques, are not subject to review. At this level, the recommendations, conclusions, findings and results developed by the mathematician are very significant, since they are generally accepted without close or detailed technical review and may be used as a basis for important policy determinations and commitments having considerable effect on agency programs. Mathematicians GS-13 make agreements with representatives of other organizations both within and outside the employees agency which commit organizational entities to participation in and support of and intra-organization programs and projects. These agree are usually confined to technical considerations within the mathematician's immediate jurisdiction and do not involve a deviation from agency policy or a change in program requirements.

Professional qualifications required

In addition to the skills and abilities required at the preceding levels, the employee should possess a thorough and detailed knowledge of broad areas of classical and modern higher mathematics and a comprehensive knowledge of a specialized branch of mathematics appropriate to the assigned area of responsibility. The employee must, possess recognized ability to originate and develop new mathematical methods and should possess a broad knowledge of recent mathematical advances in his particular field of endeavor. The skills and knowledges required at this level differ from those at the preceding level primarily in the degree of their intensity, i.e., those of an authoritative scientist. A high degree of originality, professional judgment, imagination and resourcefulness is required at this level.